Introduction to Artificial Intelligence

丁尧相
浙江大学

Fall & Winter 2022
Week 1

Outline

- Course Info
- What is AI?
- Three building blocks:
  - Decision making
  - Knowledge reasoning
  - Machine learning
- Two term goals
  - Decode math equations
  - Play Atari games
- Take-Home Messages

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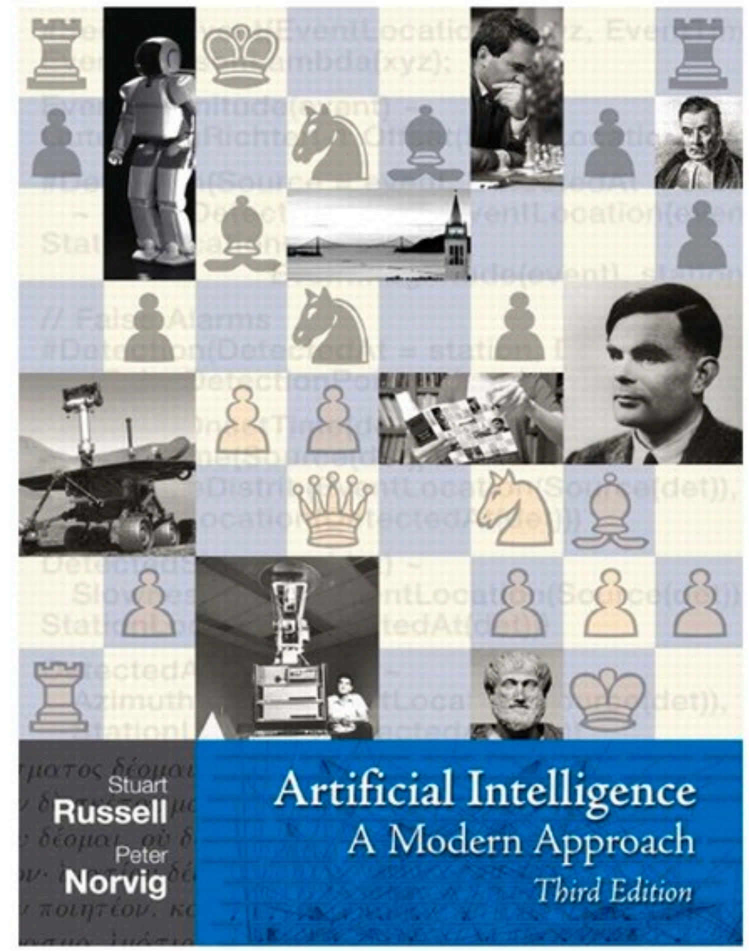
Course Info

- Time:
  - Monday 6-8 (every week)，西1-416
  - Wednesday 11-12 (lab, double week)， 紫金港机房
- Instructor: 丁尧相 dingyx.gm@gmail.com
  - Office Hour:
    - Wednesday 15:00 -17:00, Meng Minwei Bldg. 519
    - Better to make appointment on Ding Ding
- TA: 彭奕飞 buweishengrenjiweiqinshou@gmail.com
- Homepage: https://yaoxiangding.github.io/introAI-2022 (building)

Schedule

- 16 weeks
  - 13 + 0.5 + 0.5 lectures (due to the mid-term quiz and final review)
  - 7 labs
- Grading: 60% knowledge part + 40% lab part
  - Knowledge part:
    - Four problem sets 40%
    - Mid-term quiz 10% & final exam 50%
  - Lab part:
    - 4 projects
    - 5 bonus scores for the final grading (details later)

Textbook



- The textbooks are not required. We will put the necessary materials on the course homepage.

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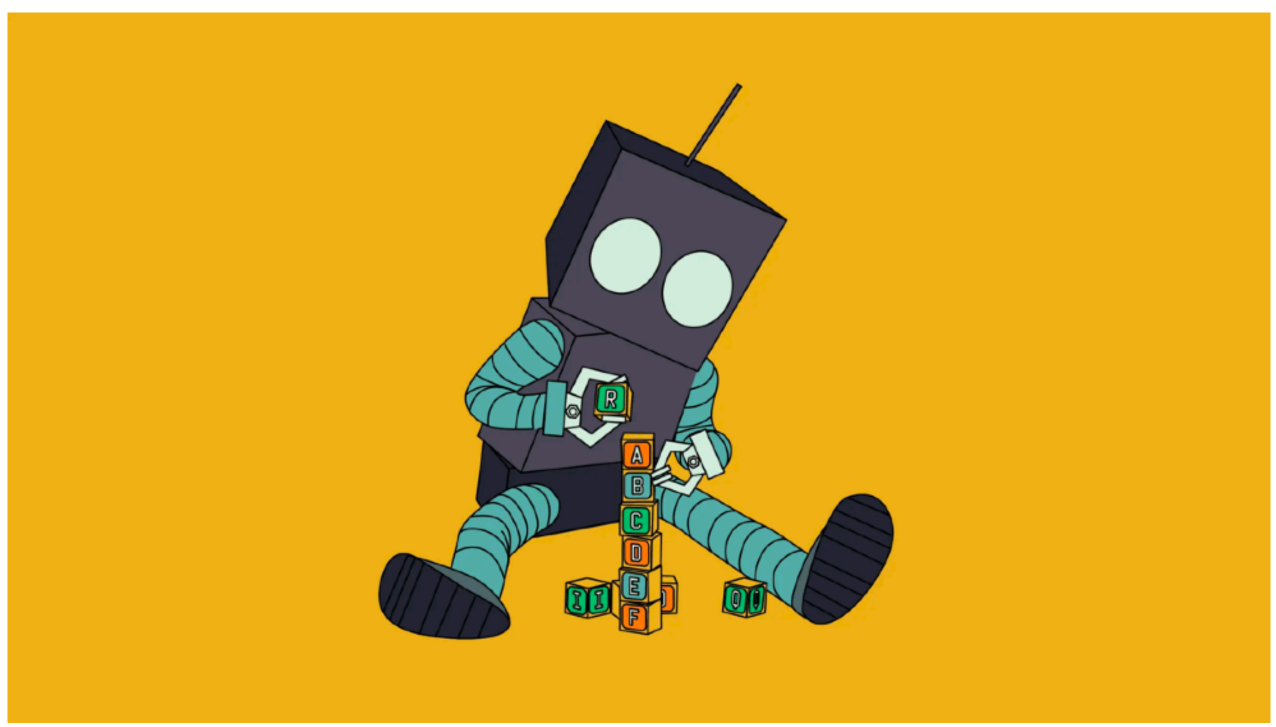
Artificial Intelligence

“Definitions demand reduction and reduction demands going to a lower rung.”

— Judea Pearl, “The book of why”.

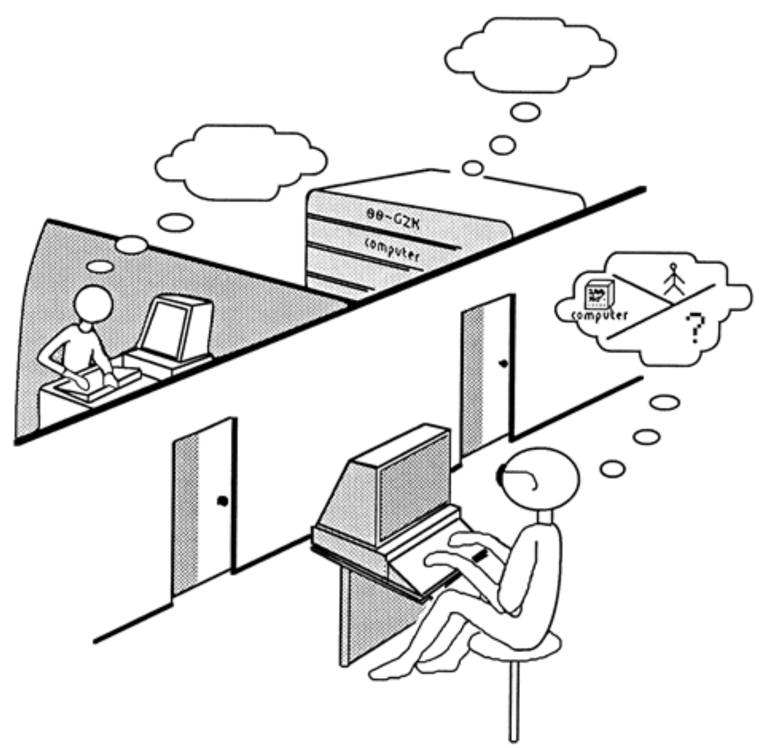


Turing Test

“The new form of game can be described in terms of a game which we call the ‘imitation game’ ”.

“Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child’s?

— Alan Turing, “Computing Machinery and Intelligence”, 1950.



Dartmouth Conference (1956)

Dartmouth Conference (1956)

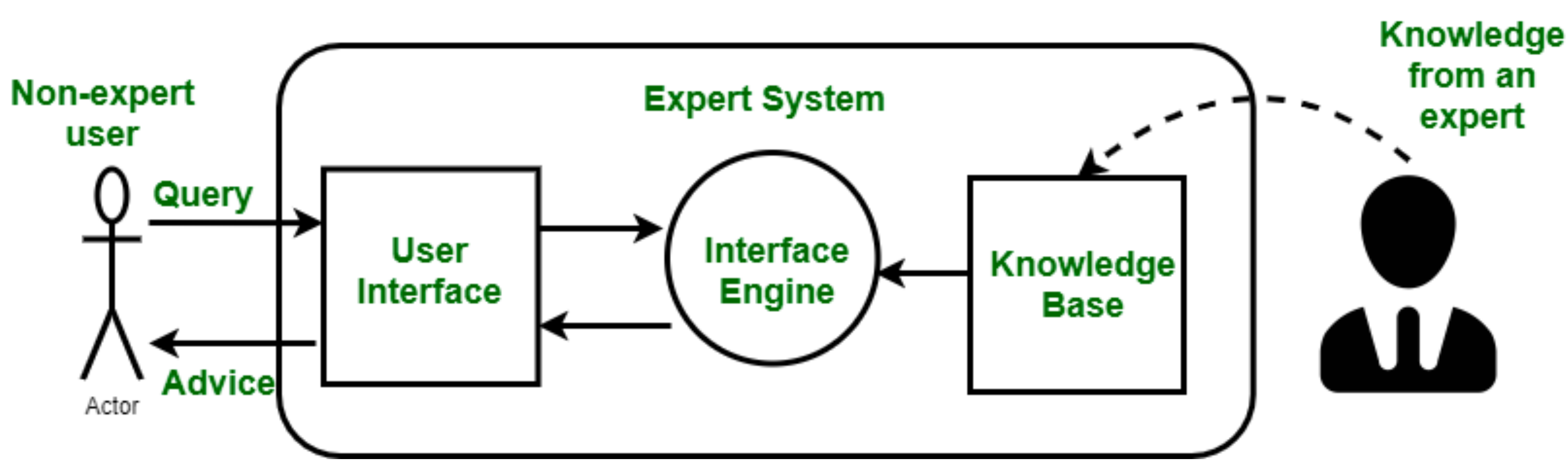
50 years later

Stage I: Problem Solving & Symbolic Reasoning (1950s-1960s)

- Newell and Simon's "Logic Theorist" and "General Problem Solver".
  - " We have invented a computer program capable of thinking non-numerically, and thereby solved the venerable mind-body problem."
- McCarthy's LISP language.
- McCulloch-Pitts neuron model (1940s) and Rosenblatt's Perceptron algorithm.
- The first AI winter (1970s)

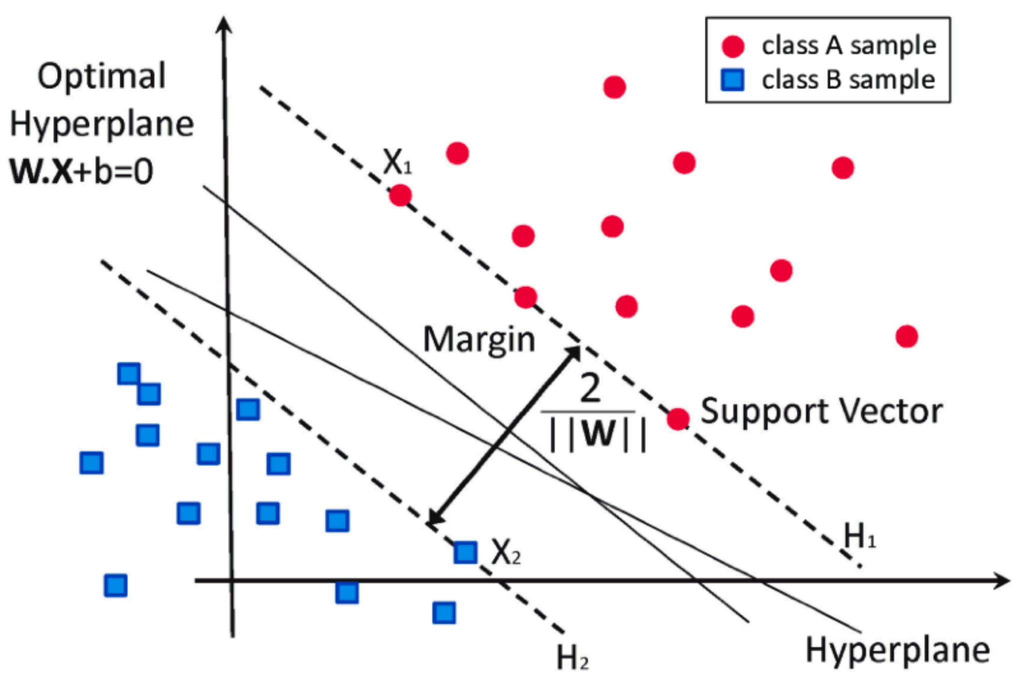
Stage II: Knowledge and Uncertainty (1970s-1980s)

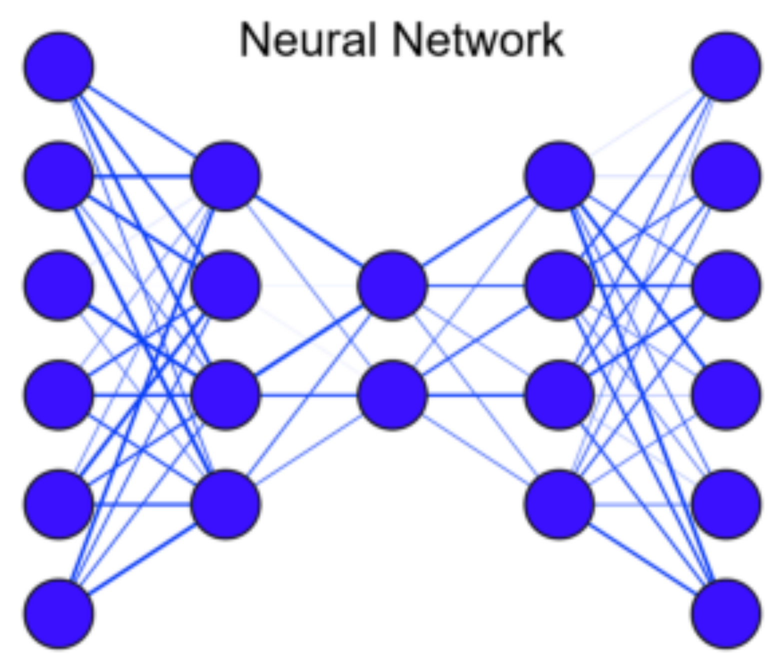
- Domain-specific knowledge system: expert system
- Reasoning under uncertainty: probabilistic modeling, graphical models
- (maybe) The second AI winter: (late 1980s - early 1990s)



Stage III: Machine Learning (1990s-Now)

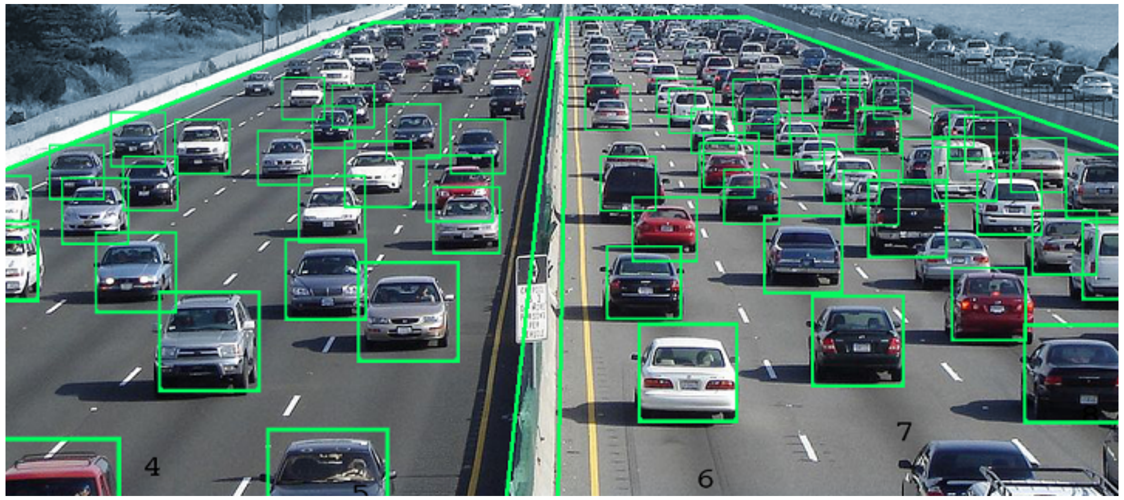
- The rise of statistical learning (root back to 1970s)
- The boost of deep learning (2006-Now)





Application Fields

- Computer vision
- Natural language processing
- Speech Recognition
- Robotics
- …



Connections to Other Fields

- Cognitive science, neuroscience, psychology
- Game theory
- Control theory, cybernetics
- …

If we still need a definition for AI…

AI is a subfield of computer science with connections on many other fields. The goal is to build machines that think and act rationally and intelligently.

What Will You Learn in This Course?

- What won't you learn in this course? (apologize :-P)
  - computer vision, natural language processing, robotics
  - neural science, cognitive science
  - fancy applications
- What will you learn in this course?
  - The core techniques that allow machines to:
    - Obtain insightful knowledges via their own imperfect perceptions.
    - Make rational decisions in a complicated and uncertain world.

Build a routine that guides you to the frontier of AI.

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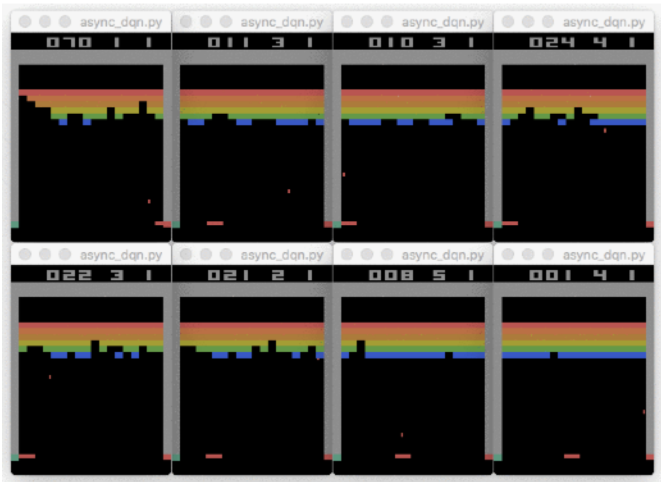
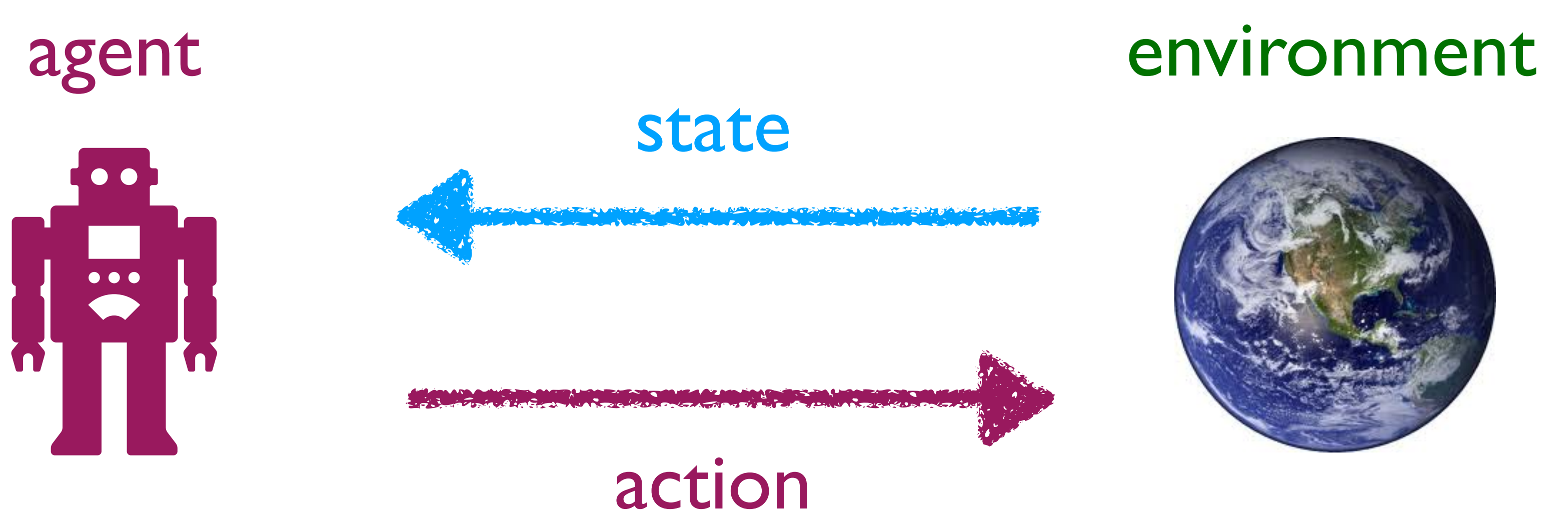
Decision Making



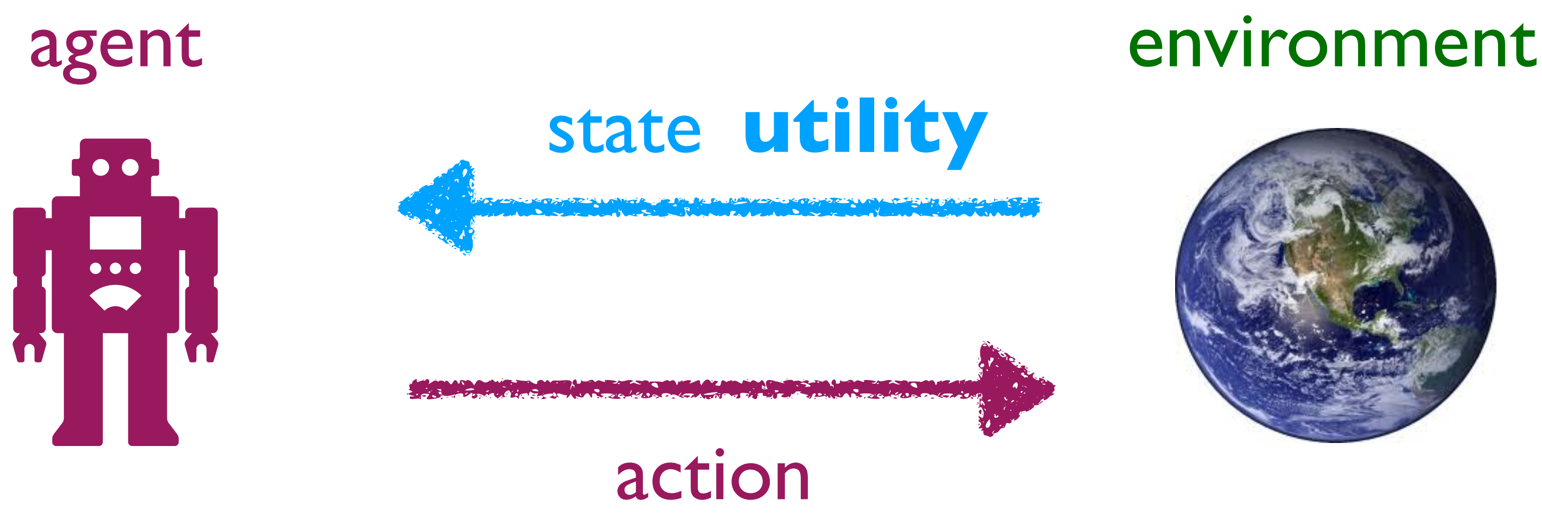
- Conduct action in any state of an environment.



In most problems, the agent needs to do a sequence of actions w.r.t. a sequence of states.

Goal & Utility

Goal & Utility

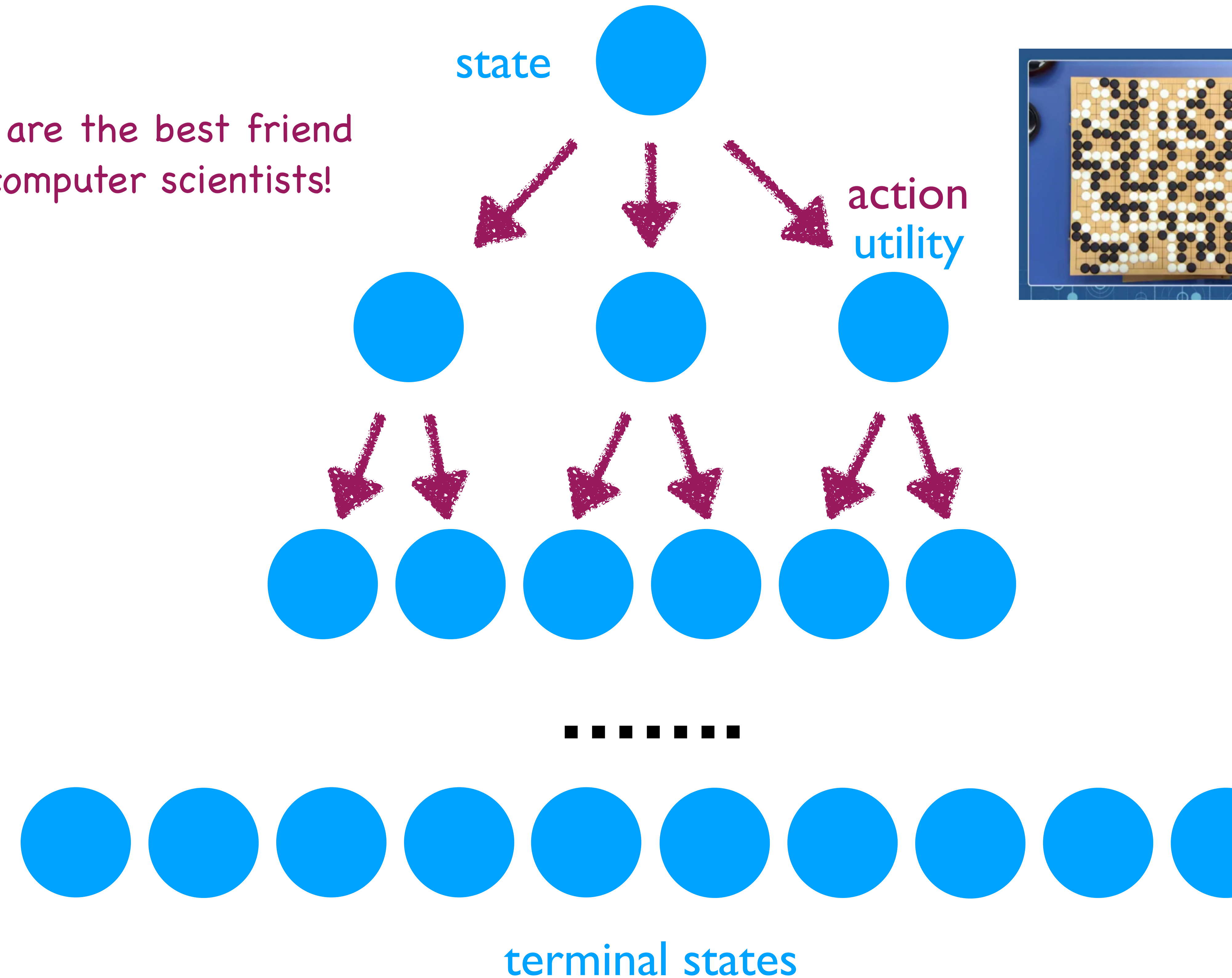


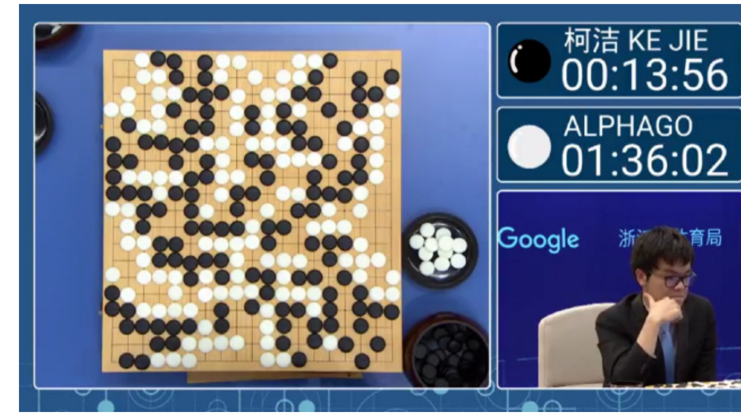
- What is the best actions that the agent can take?
  - Reach a goal with the minimal cost.
  - Obtain the most accumulative utilities along the sequence.

Goal-reaching and utility-maximizing agents are rational.

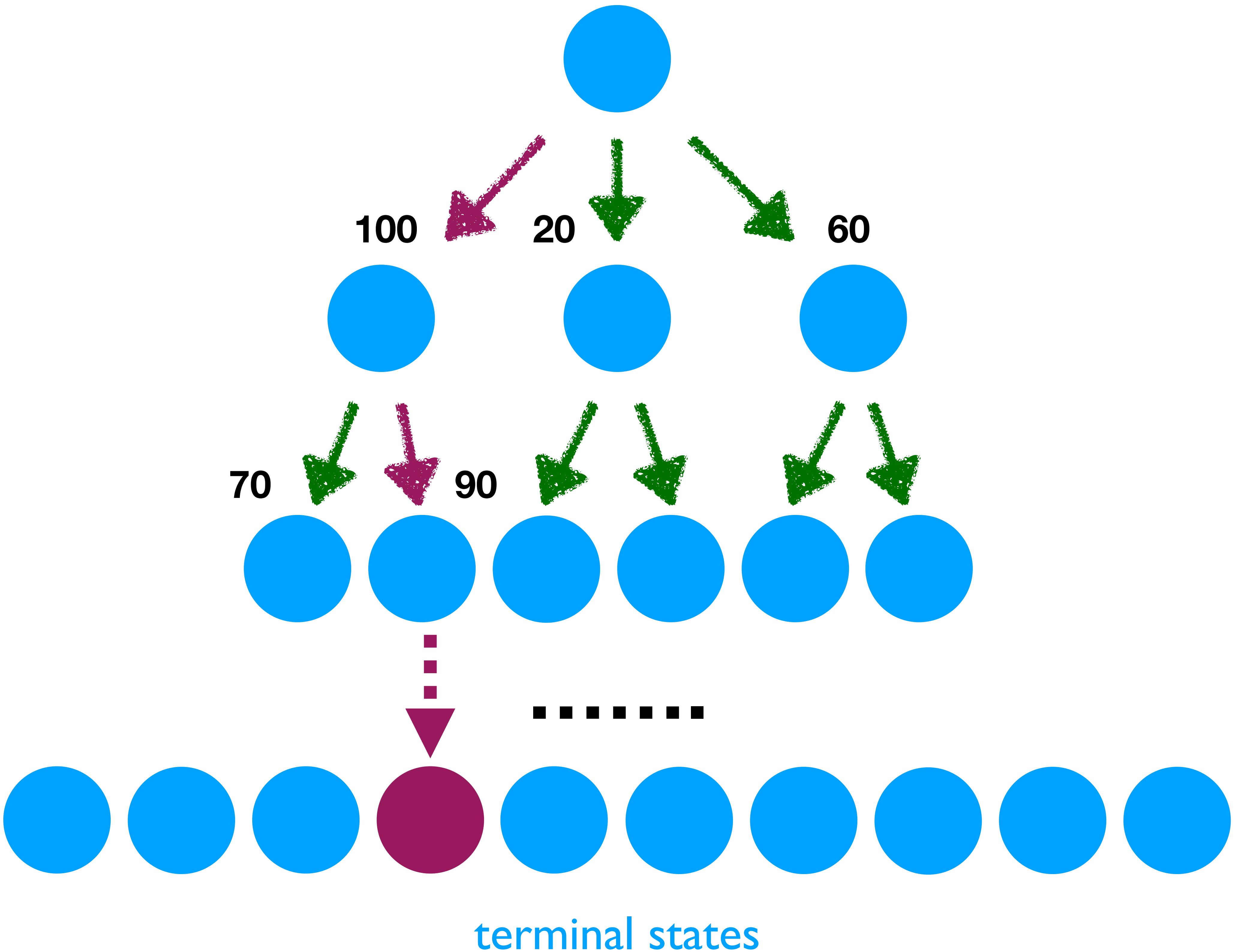
Model of Decision Making

Trees are the best friend for computer scientists!





Search: the Basic Strategy for Decision Making

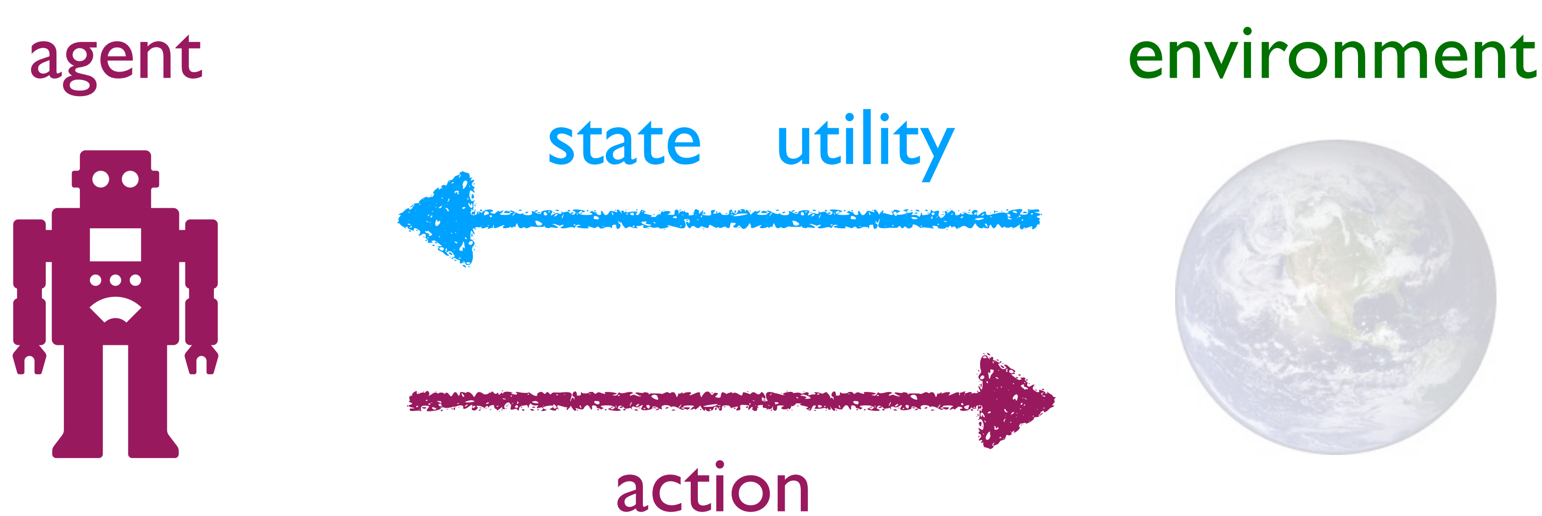


Challenges for Search Strategy

Personal perspective: Decision making is the central problem for AI.
But why strong AI is not reached when the machines can do search?

In most real AI problems,

- Search may not be computational tractable.
    - We will learn many strategies to do search smartly.
- The model (environment) may not be fully known by the agent.
    - The agent should build the model by itself.



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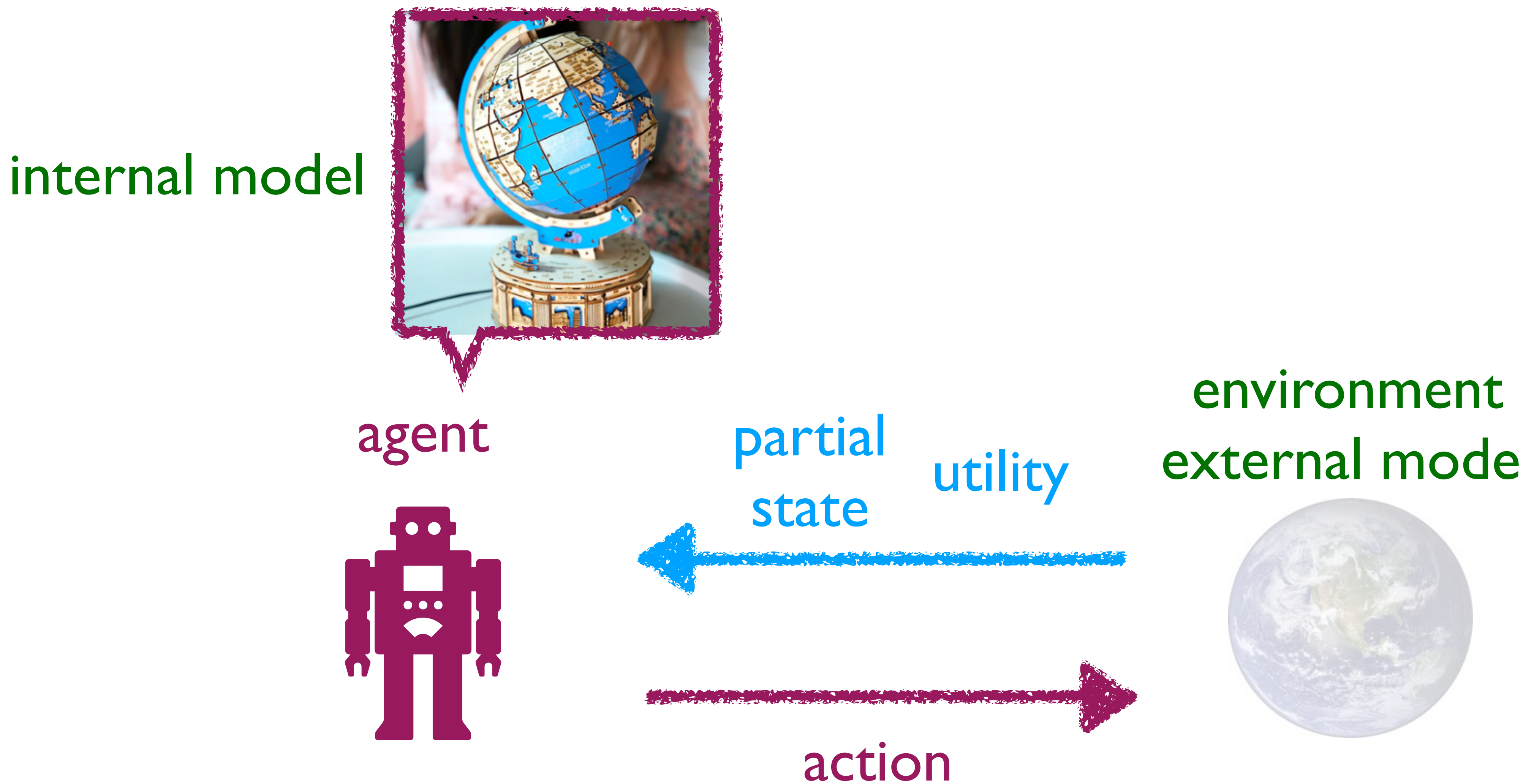
Internal vs. External Model

Since the agent cannot fully know the external model,
it should build an internal model itself for decision making.



Reasoning in the Internal Model

- Turn primitive external states into meaningful internal states.
- Reason about most useful states for decision making.

These reasoning rules are called knowledges in an AI system.

Decision Making & Knowledge Reasoning

- We will learn three kinds of knowledge reasoning strategies:
  - logic inference, probabilistic inference, causal inference.
- Decision making & knowledge reasoning will be the first half of this course (the next 6 lectures).

The second half (6 lectures) will focus on machine learning:
Obtain the ability to do decision making and knowledge reasoning by learning from experience.

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Machine Learning

In machine learning, we want to obtain these programs (functions) by learning from experience instead of programming by hand.

Computer Program

Input		Output
numbers	$\longrightarrow$	sorts
graph		shortest path
random seed		pseudo-random numbers
items: {weight, value}		knapsack solution
images		classes
game		actions to play

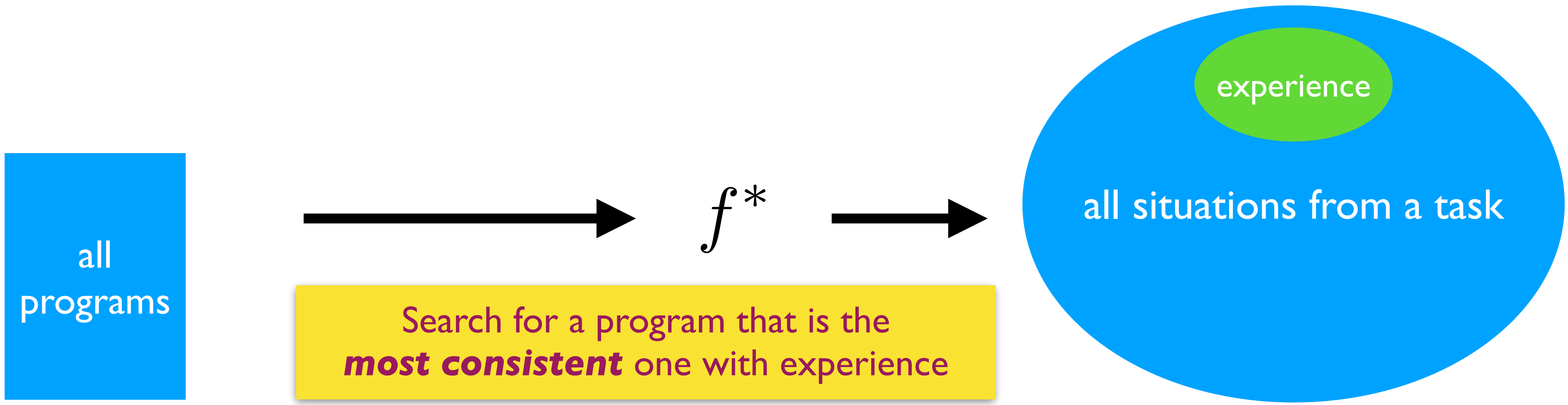
Machine Learning

numbers		sorts
graph		shorted path
random seed	→	pseudo-random numbers
items: {weight, value}		knapsack solution
images		classes
game		actions to play

- Do all computer programs need to be obtained by machine learning?
  - When learning is hard but programming-by-hand is easy: NO!
  - When programming-by-hand is hard but learning is easy: YES!

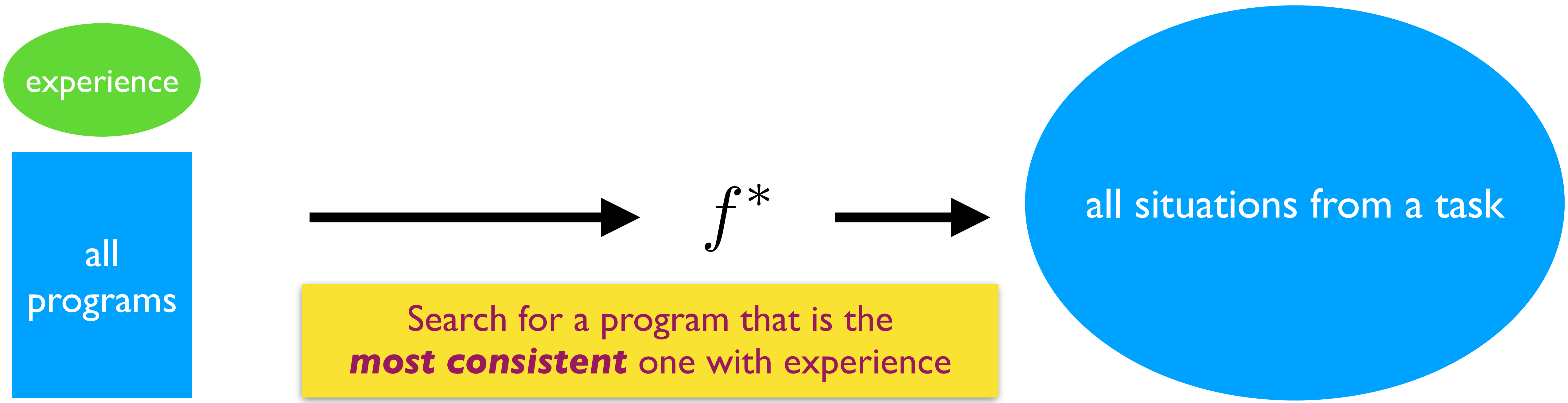
When will learning be possible?
When learning is possible, how to learn efficiently?
Similar to fundamental problems of computation.
What's the difference?

Basic Mechanism



- When will learning be possible and easy?
  - When limited experience can represent all situations.
  - When searching for the best program can be done efficiently.

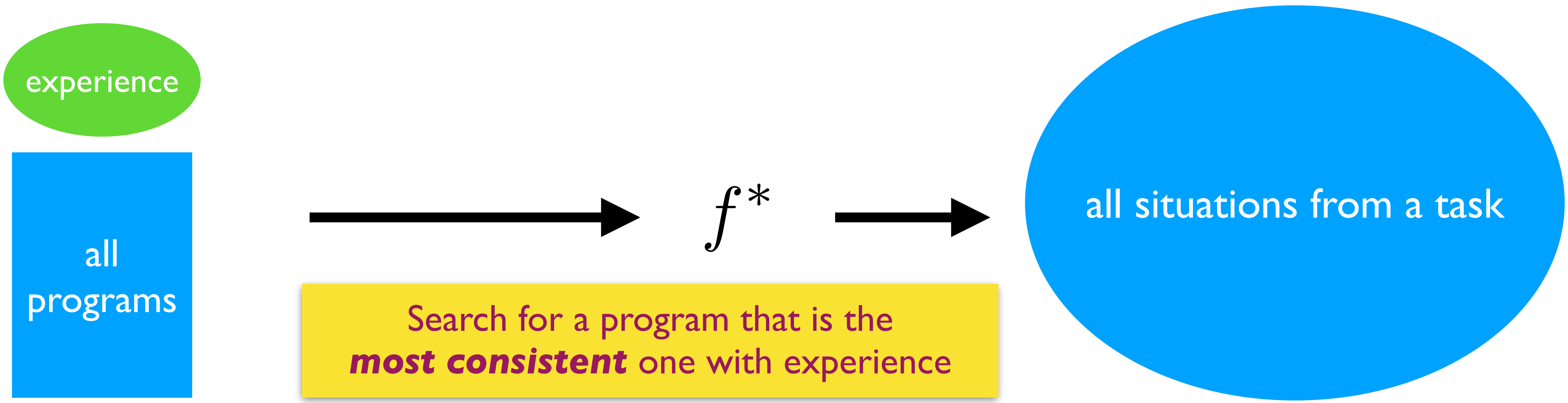
Machine Learning is a Statistical Problem



- When will learning be possible and easy?
  - When limited experience can represent all situations.
  - When searching for the best program can be done efficiently.

Obtain general rule from limited experiences: **statistics**.
Basic principle: the law of large numbers.

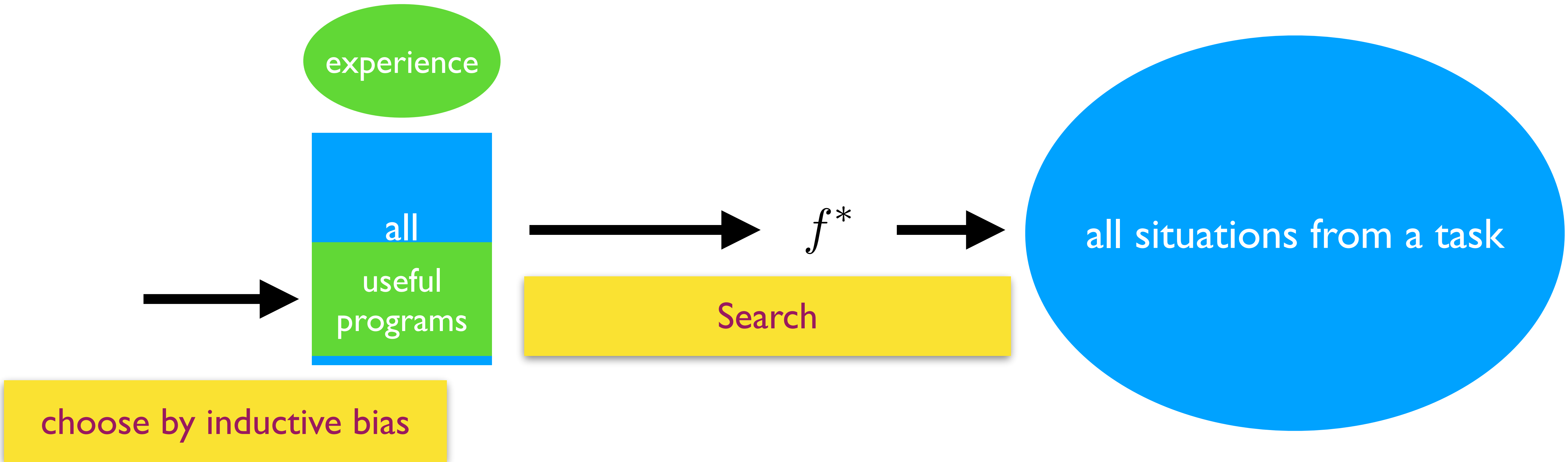
Machine Learning is a Computation Problem



- When will learning be possible and easy?
  - When limited experience can represent all situations.
  - When searching for the best program can be done efficiently.

Searching from the optimal solution: **Optimization**.
Optimization is a computation problem.

Inductive Bias in Machine Learning



- Learning is both statistical and computational.
  - We care about both statistical and computational complexity.
  - Humans can learn from very few experiences and very fast. Why?

Not all programs are born equal.
Humans choose the right **inductive bias** to reduce the program set.

Machine Learning: Theory, Algorithm, and Application

- Machine Learning Theory:
  - Understanding the foundations: when will learning be easy?

theoretical computer science, statistics, game theory, information theory…

- Machine Learning Algorithm:
  - Design models and algorithms for *general* machine learning problems.
- Machine Learning Application:
  - Design inductive bias for different applications, e.g. CV, NLP.

Machine Learning Scenarios

- Supervised learning
  - Classification
  - Regression
  - Ranking
- Unsupervised learning
  - Clustering, density estimation
  - Generative modeling
- Semi-supervised learning
- Reinforcement learning
- …

learn from pre-given data

learn from self-generated data

Machine Learning Methods

- Symbolic Learning
- Frequentist statistical learning
  - Support vector machine, kernel method
  - Decision tree, random forest, boosting
- Bayesian statistical learning
  - Graphical models
  - Variational inference and approximate sampling
- Neural networks
  - Deep learning

No absolute boundaries!

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Lab Projects

- 4 lab projects:
  - Search
  - Knowledge reasoning
  - Supervised/unsupervised learning
  - Reinforcement learning

We expect that after learning this course,
you are able to build one of the following two systems!
(and get the bonus scores :-P)

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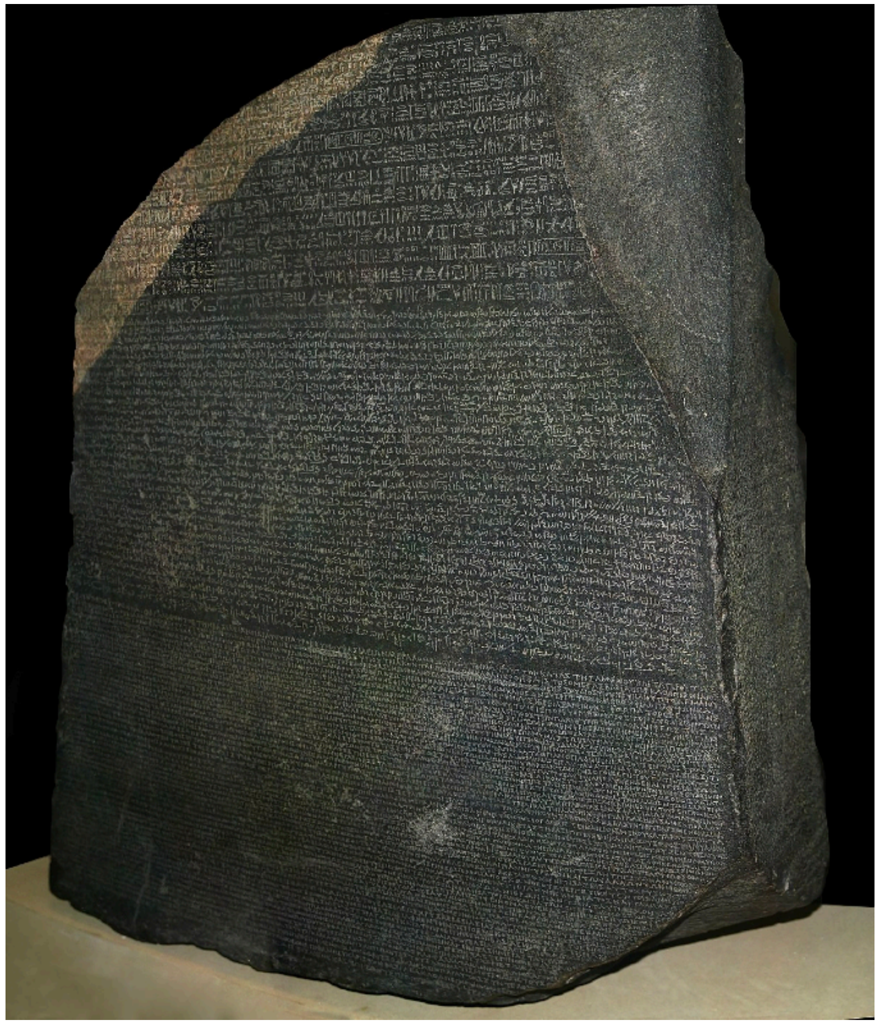
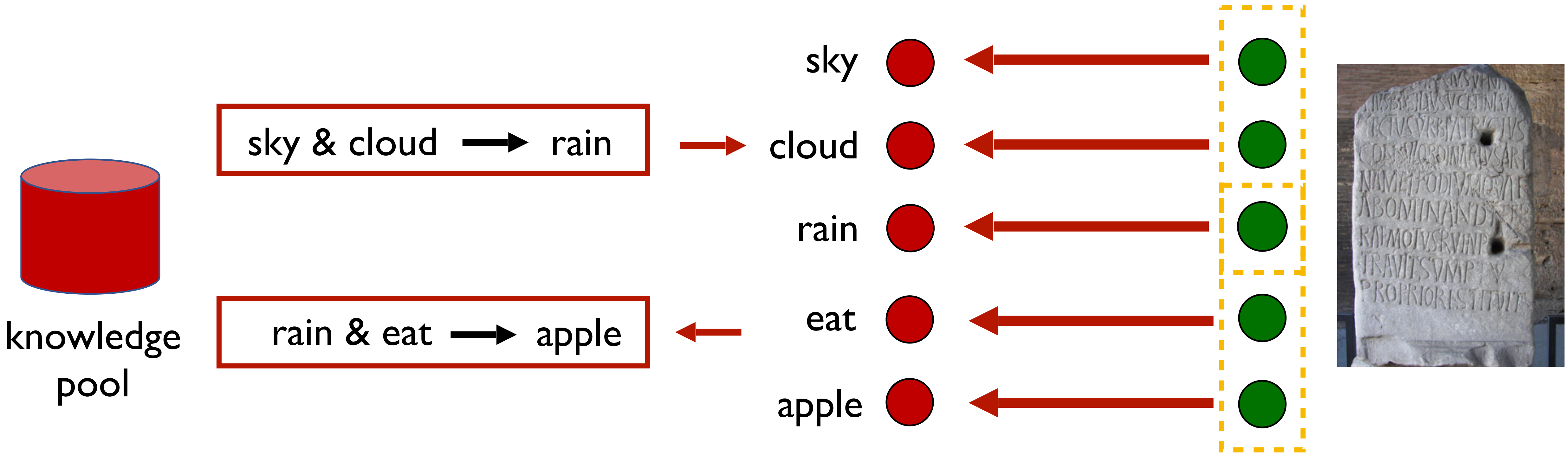
Imaging You Are an Archaeologist…

How you decode these characters?



Decoding via Reasoning & Learning



- Supervise character recognition by knowledge rules
- Learn new knowledge rules from recognition result

Bridge knowledge learning, reasoning and low-level perception learning.
A frontier of machine learning research.

Decoding Math Equations

Don’t be afraid.
You AI will not need to be an archaeologist.
It just needs to be a primary school student. :-P

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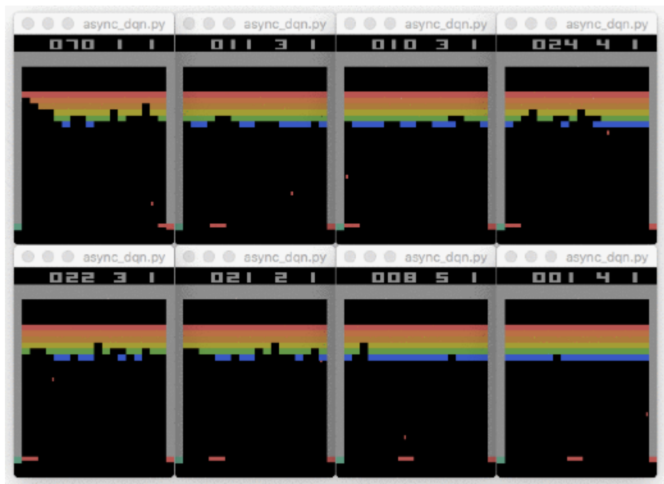
Reinforcement Learning

- Reinforcement Learning is learning to make decisions.

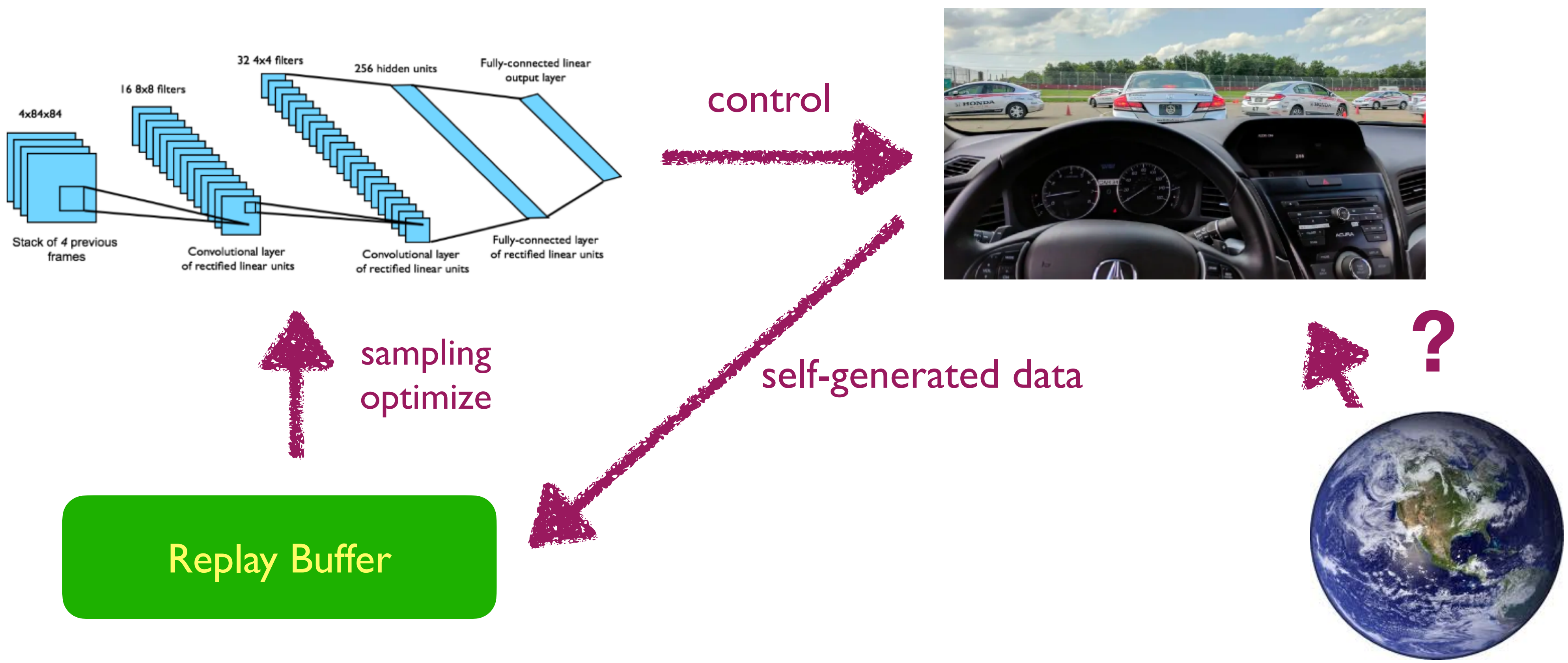


- The agent faces a series of states.
- Need to choose the corresponding actions.
- Target: maximize the total reward.

The agent learns from self-generated data in the world.

Why hasn't DRL solved many real-world problems?

- Deep RL usually does not use (learn) a world model.



Without a world model, learning from self-generated data requires many trial-and-errors in the real world.
Large cost. Bad generalization to new task.

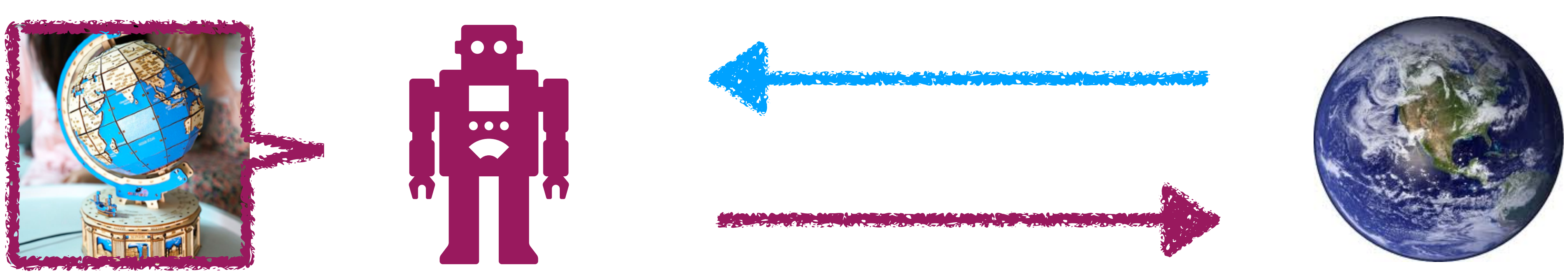
Reinforcement Learning with Models

Scenarios of decision making:

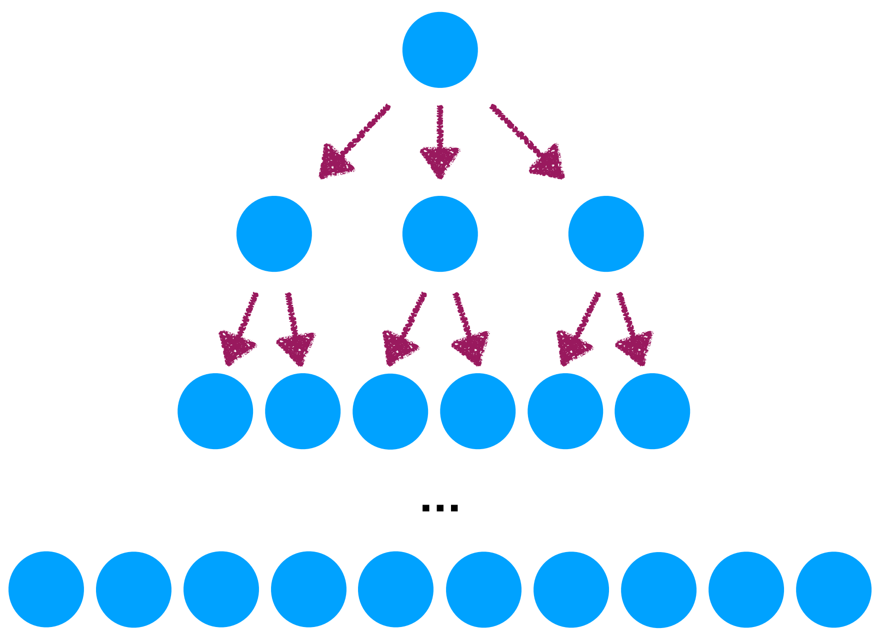
- Planning: directly solve the optimal policy when the world model is known (dynamic programming, Monte-Carlo tree search…)

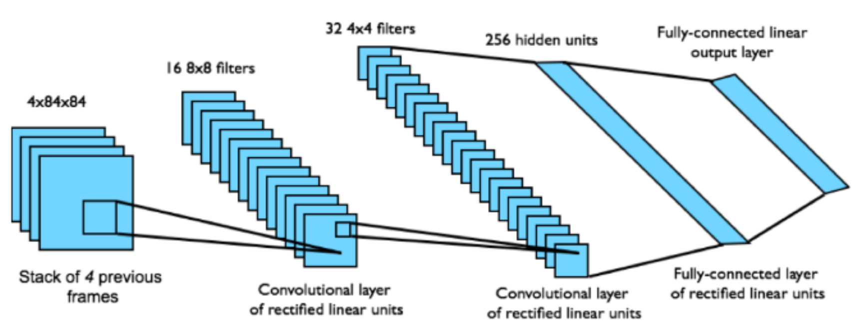
- Model-free RL: learn by trial-and-error (Q-learning, policy gradient, actor-critic…)

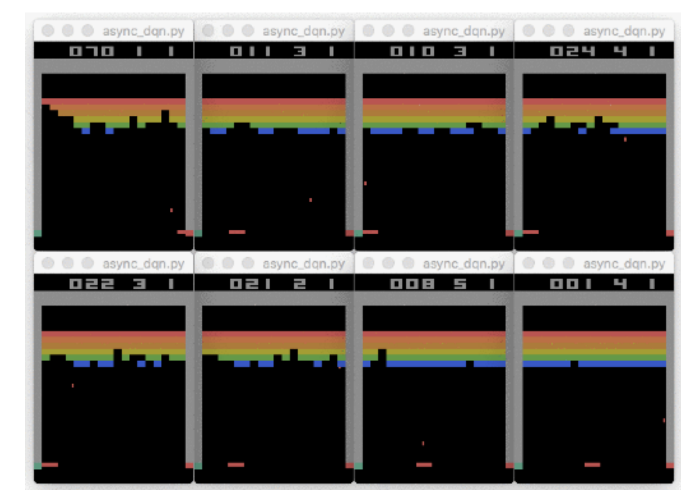
- Model-based RL: learn the world model during learning, do RL or planning using the model.



Playing Atari Games by Both Planning & Learning







Basic strategy behind many state-of-the-art decision-making AIs.
The key challenge lies in building a good internal model.

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Take-Home Messages

- AI $\neq$ machine learning
- machine learning $\neq$ deep learning
- What will be covered in this course:
    - Decision making, knowledge reasoning, machine learning
- We try to study the techniques to build the following two agents:
    - Obtain insightful knowledges via their own imperfect perceptions.
    - Make rational decisions in a complicated and uncertain world.

Thanks for your attention!
Discussions?